# Altitudinal Distribution of Endemic Psyllids (Homoptera: Psyllidae) in the *Metrosideros* Ecosystem[1]

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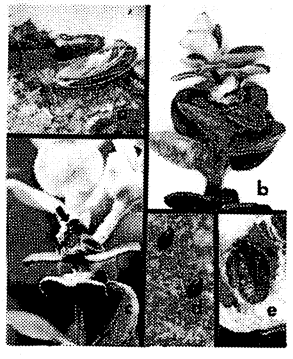
Mountains are one of the conspicuous topographic features of the Hawaiian Islands. Because of these features, altitude-associated factors are of great importance to the island ecosystem. The present study is concerned with endemic psyllids in the *Metrosideros collina polymorpha* var. *incana* ecosystem in the Hawaii Volcanoes National Park on the slopes of Mauna Loa.

Psyllids, Homoptera: Psyllidae, are one of the major groups of primary consumers in *Metrosideros* ecosystem. The adults, Fig. la, are small fragile insects, approximately 2-4 mm in length. The eggs, Fig. 1d, are laid on terminal shoots either on old growth or young shoot. They are 0.2-0.3 mm in length, yellow or black depending on species, and laid with one end partially imbedded in the host tissue. Upon hatching, the nymphs of most species, Fig. le, produce galls of various shapes depending upon the species, Figs. 1 and 2. They develop within the galls, emerge from them when fully grown, and molt into adults outside of the galls. In certain areas extensive damage resulting from deformation of terminal leaves and stems, was observed.



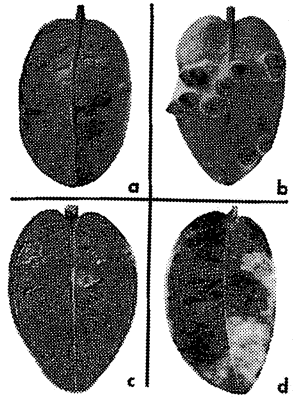




Fig. 1. Galls and life stages of *Trioza hawaiiensis* Crawford on *Metrosideros*:a. adult; b, stem gall; c, stem gall with emergence hole of mature nymphs; d, eggs; e, nymph. Arrows show location of galls on stems.

Fig. 2. *Metrosideros* leaves showing galls and discolorations made by different species of psyllids: a, flat galls by *Trioza* n. sp. no. 1; b, cone galls by *Trioza* n. sp. no. 2; c, pit galls by *Kuwayama minuta* Crawford; d, feeding discolorations by *Kuwayama* n. sp. a and b, ventral surface of leaf; c and d, dorsal surface of leaf.

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There is very little information in the literature on the ecology and biology of Hawaiian psyllids. Previous work has been taxonomic studies, mainly by Crawford (1918) and Caldwell (1949). According to Swezey (1954) there are in the Hawaiian Islands a total of 10 species of psyllids on *Metrosideros*. Having found three undescribed species in such a small area in this study, the present authors feel that there are many more new species in other localities.

## Methods

### *Study Area*

This study was carried out during 1971-72 on the Island of Hawaii at the Hawaii Volcanoes National Park where the *Metrosideros* ecosystem extends from sea level to about 8,500 feet up the slopes of Mauna Loa. A transect, approximately 23 miles long and referred to in this paper as the Mauna Loa transect, was established from sea level to 8,000 feet, Fig. 3. Because of recent volcanic activity the soil along this transect is mostly lava rocks and cinders; in other areas on weathered parent material. In some areas volcanic activity is still going on. Some of our initial lower elevation stations were lost to lava flows.

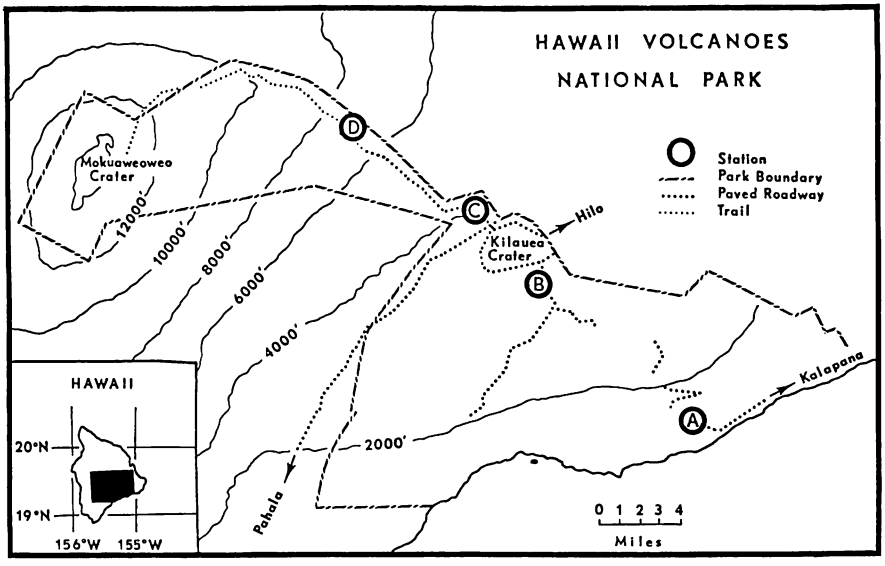


Fig. 3. Map of the Hawaii Volcanoes National Park showing the Mauna Loa transect and the sampling stations.

The vegetation varied with elevation. Only a brief description is given here because it is not the purpose of this paper to describe vegetation. The vegetation around Station A at 50 feet was sparse. The only trees in the area were isolated stands of *Metrosideros*. However, around Stations B and C at 3,500 and 4,000 feet, *Metrosideros* and other plants were dense and diverse. Further up the transect at Station D at 7,000 feet and above, the predominant vegetation was scattered *Metrosideros* with low shrubs, chiefly *Styphelia,* interspersed among them.

Temperature varied greatly and rainfall slightly with increasing elevation along the Mauna Loa transect. The monthly mean minimum and maximum temperatures from July, 1971, to June, 1972, were respectively: 19.3°C and 29.8°C at 50 feet; 9.0°C and 23.0°C at 3,500 feet; 6.1°C and 23.0°C at 4,000 feet; and 2.2°C and 19.9°C at 7,000 feet. The total annual rainfall for the same period at the same elevations were respectively 160, 190, 160, and 160 cm.

*Sampling*

Psyllid adults were sampled monthly by use of a D-vac suction machine from *Metrosideros* at each sampling station slong the transect. A sample consisted of psyllids collected by sucking the terminal leaves and twigs of *Metrosideros* for five minutes. On each sampling date, four samples were taken from each station. The psyllids sampled were killed in the field and later identified and counted in the laboratory. Besides adult sampling, data were taken on incidence of psyllid attack on *Metrosideros* at various elevations.

From the data obtained indices of diversity and dominance were calculated. The Shannon index of general diversity was calculated in accordance with Shannon and Weaver (1963). The index of dominance was calculated by the method of Simpson (1949).

## Altitude Related Phenomena

*Psyllid species and attack symptoms*

Swezey (1954) listed a total of 10 apecies of psyllids on *Metrosideros* from the Hawaiian Islands. Two species listed by Swezey and three new species were present along the Mauna Loa transect: *Trioza hawaiiensis* Crawford, *T.* n. sp. no. 1, *T.* n. sp. no. 2, *Kuwayama minuta* Crawford, and *K.* n. sp.

Distributional data obtained from the Mauna Loa transect showed that the species composition on *Metrosideros* varied along the transect, Table 1. At Station A there were three species, and at Stations B, C. and D, four species.

TABLE 1. *Types of galls and percentage of psyllid species sampled from* Metrosideros *at various sampling stations along the Mauna Loa transect during* 1971-72.

| Species | Gall type produced | Percentage at indicated stations | | | |
|---|---|---|---|---|---|
| | | A (50 ft.) | B (3,500 ft.) | C (4,000 ft.) | D (7,000 ft.) |
| | | (n=948) | (n=1,671) | (n=1,772) | (n=421) |
| *Trioza n. sp no. 1* | flat | 95.5 | 44.8 | 42.7 | 20.4 |
| *T. n. sp. no. 2* | cone | 0.7 | 46.7 | 23.9 | 0.2 |
| *T. hawaiiensis* | pit | 0.0 | 3.7 | 18.2 | 37.3 |
| *Kuwayama minuta* | pit | 0.0 | 6.1 | 16.0 | 42.0 |
| *K. n. sp.* | none | 3.6 | 0.0 | 0.0 | 0.0 |

The presence of each of these species can be recognized by the characteristic symptoms on *Metrosideros*. It was found that *T. hawaiiensis* produced stem galls, Fig. 1b and c; *T. n. sp. no. 1*, flat galls, Fig. 2a; *T.* n. sp. no. 2, cone galls, fig. 2b; and *K. minuta*, pit galls, Fig. 2c. Galls were not produced by *K. n.sp.* Its feeding symptoms appeared as discolorations on the upper leaf surface, Fig. 2d.

Table 1 shows the occurrence of attack symptoms of each species at different stations. In general it seems that the gall-formers had wider elevational ranges than the non-gall former. The pit gall-formers were predominant at 7,000 feet and the flat gall-former at 50 feet. Whether or not gall types have any relationship to species adaptation to the environment is not known. If we assume that all the *Metrosideros* along the transect were the same, then we must assume that the kind of gall produced is dependent upon the insect rather than the plant.

The data obtained on the incidence of galls indicated surprising low values. The highest percentage of galling was only 10 to 23 percent galled leaves. This low galling rate indicates that the availability of leaves is not the limiting factor to psyllid abundance. Natural enemies may be involved. Natural Enemies such as *Pauahiano swezeyi* Yoshimoto, *(Eulophidae) Anystis* sp. *(Acarina)*, spiders, *(Araneae)* and coccinellids were often observed on *Metrosideros*. Their role in the regulation of the population of psyllids is not known.

*Species distribution*

Continuous and discontinuous distributional patterns were found along the Mauna Loa transect, Figure 4. For example, *T. n. sp. no. 1* was found continuously distributed from 50 to 8,000 feet, *T. n. sp. no. 2* from 50 to 6,500 feet, and *K. n. sp.* from 50 to 3,000 feet. Discontinuous distribution was observed in *K. minuta* and *T. hawaiiensis*. The former was

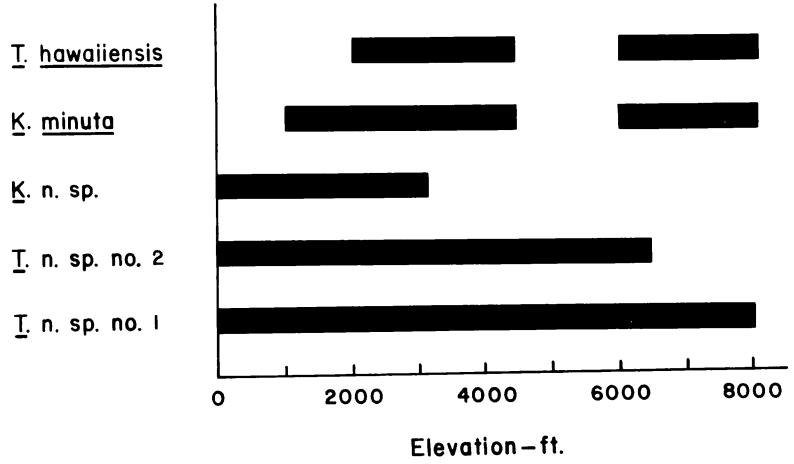


Fig. 4. Continuous and discontinuous distribution of the five species of psyllids associated with *Metrosideros* along the Mauna Loa transect.

present at 1,000 to 4,500 feet and also at 6,000 to 8,000 feet. The latter species was present at 2,000 to 4,000 feet and at 6,000 to 8,000 feet.

*Coexistence*

There were five species of psyllids that coexisted and exploited the same resource in the *Metrosideros* ecosystems of the Mauna Loa transect. They all fed and reproduced on young terminal shoots of *Metrosideros*. According to Root (1967), a group of sympatric species that exploits a common resource constitutes a guild. According to this concept the psyllids associated with *Metrosideros* may be considered a guild. As shown in Table 1, the guild at 50 feet consisted of *T. n. sp. no. 1, T. n. sp. no. 2* and *K. n. sp.* At 3,500 , 4,000, and 7,000 feet it consisted of *T. n. sp. no. 1, T. n. sp. no. 2, T. hawaiiensis,* and *K. minuta.*

*Carrying capacity*

According to the logistic population growth theory a population ultimately reaches an asymptotic value, a value known to ecologists as K or the carrying capacity. Because the psyllids in the present study have been a part of th *Metrosideros* ecosystem for a long period, it is assumed that each

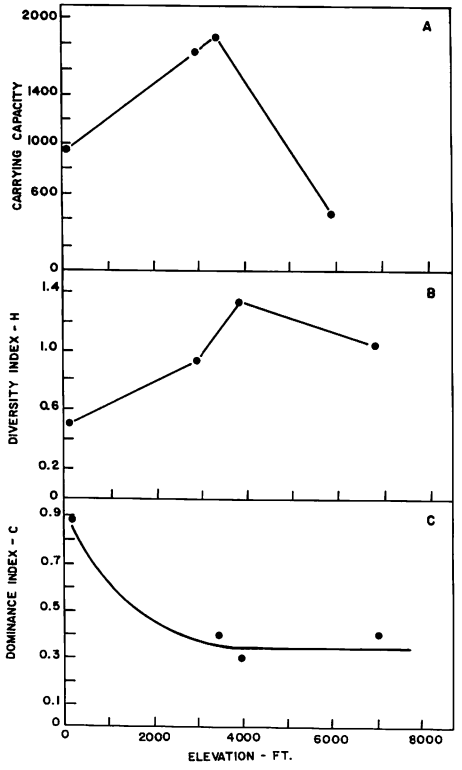


Fig. 5. Relationship between elevation and three ecological phenomena along the Mauna Loa transect: A, carrying capacity of the environment; B, species diversity (H); and C, dominance (c).

population had reached the asymptotic value under existing conditions. For this reason the summation of the samples taken during the year may be considered to be an index of the carrying capacity of the respective sampling stations along the Mauna Loa transect.

The carrying capacity values at various elevations are shown in Figure 5A. It shows that the carrying capacity increased from 50 to 4,000 feet and then decreased with increasing elevation up to 7,000 feet. Because of the high carrying capacity at 3,000 to 4,000 feet, it can be concluded that these elevations are the most favorable areas for psyllids. Field observations showed that the *Metrosideros* at these elevations was more vigorous and taller than either the lower or higher elevations.

*Species diversity*

As mentioned elsewhere in this paper the number of species of psyllids as well as the abundance of each varied with elevation. Since indices of species diversity are useful in summarizing data on number of species and individual numbers, the data on all sampling of adult psyllids from each station were pooled and the Shannon Index ($\bar{H}$) calculated (Shannon and Weaver, 1963).

The relationship between indices of species diversity and elevation is shown in Figure 5B. It shows that the $\bar{H}$ values increased from 50 to 4,000 feet elevation and then declined as the elevation increased. The interpretation of H values in a community is complicated. However, in the present study, high H values at intermediate elevations are interpreted to mean that the physical and biological environments are such that the population and number of species of psyllids are higher here than at other elevations.

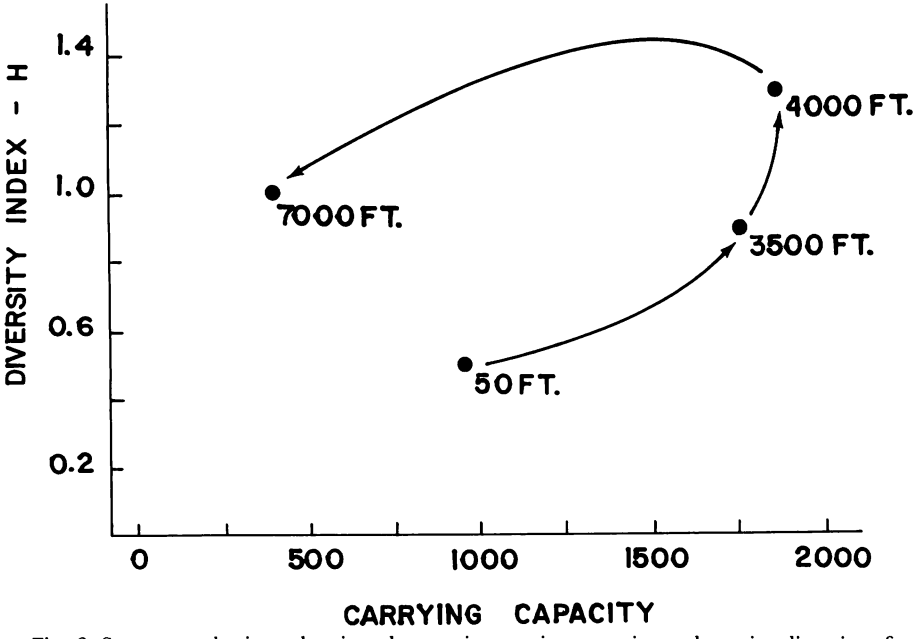


Fig. 6. Sequence plottings showing changes in carrying capacity and species diversity of psyllids at various elevations along the Mauna Loa transect.

*Species diversity and carrying capacity*

Sequence plottings were made to determine changes in diversity, $\bar{H}$, and carrying capacity at various elevations along the Mauna Loa transect, Figure 6. There was an increasing trend in $\bar{H}$ values and carrying capacity from 50 to 4,000 feet. However, both the $\bar{H}$ values and carrying capacity decreased at 7,000 feet. Therefore, the curve, instead of following the expected upward trend, reversed back towards a lower level.

*Dominance*

The data obtained from the Mauna Loa transect were used in the calculation of the index of dominance, c, (Simpson, 1949) which is a measure of the relative importance of the respective psyllid species as primary consumers in the *Metrosideros* ecosystem. As shown in Figure 5C, an index of 0.88 was the highest at the lowest elevation of 50 feet. The index then dropped to 0.38 as the elevation increased to about 3,500 feet.At elevations above this the index remained the same.

It is not the purpose of this paper to go into the discussion on the controversial cause and interpretation of dominance. However, we would like to mention a few things pertinent to this study. At the lowest elevation, where the dominance index was the highest, *T. n. sp. no. 1* was the most abundant species. Evidently, this species has the biological attributes that enable it to be more successful than others in the type of environment at low elevations. However, at higher elevations under different environmental conditions all other species seemed to be equally successful as far as survival is concerned. One interpretation of dominance values is that they are high in areas of extremely unfavorable conditions. According to this interpretation it appears that conditions at low elevations are not favorable to psyllid species except *T. n.sp. No. 1.*

## Discussion

This paper is concerned with altitudinal distribution of psyllids in the *Metrosideros* ecosystem. The relationship between a number of ecological phenomena and elevation has been discussed. It should be kept in mind that elevation *per se* was not the critical factor involved. The critical factors were the elevation related variables which were not identified in this study.

Five species of psyllids were found on *Metrosideros* along the Mauna Loa transect. Their distribution was both continuous as well as discontinuous even though the distribution of *Metrosideros* was continuous. The cause of this type of distribution can only be speculated. For example, it could be related to the genetic variability of *Metrosideros.* This was evidenced by great variation in leaf shape, leaf texture, bark texture, seasonal flowering, and flushing behavior.

The concept of guilds (Root, 1967) was mentioned in relation to the coexistence of psyllids. The guild concept implies harmonious coexistence of several species of psyllids on the terminal shoots of *Metrosideros.*

Detailed studies on resource utilization by each species is needed to understand how this coexistence is possible.

## Summary

Altitudinal distribution and related ecological phenomena of psyllids in the *Metrosideros* ecosystem are reported. The study area included a 23-mile transect extending from 50 to 8,000 feet in the Hawaii Volcanoes National Park on the slopes of Mauna Loa. Five species of psyllids, four gall formers and a non-gall former, were found along the transect. Continuous and discontinuous distributions were observed. The carrying capacity of the *Metrosideros* ecosystem varied with elevation. Indices of dominance and diversity of psyllids also varied with elevation.

## References

Caldwell, J.S. 1940. New genera and species of jumping plant-lice from the Hawaiian Islands with descriptions of several immature stages (Homoptera: Psyllidae). Proc. Hawaii Entomol. Soc. 10(3):389-397.

Crawford, D.L. 1918. The jumping plant lice (Family Psyllidae) of the Hawaiian Islands. A study in insect evolution. Proc. Hawaii. Ent. Soc. 3(5):430-457.

Root, R.B. 1967. The niche exploitation pattern of the blue-gray gnat catcher. Ecol. Monog. 37(4)317-350.

Shannon, C.E. and W. Weaver. 1963. The mathematical theory of communication. Univ. of Illinois Press, Urbana: 117 pp.

Simpson, E.H. 1949. Measurement of diversity. Nature 163:688.

Swezey, O.H. 1954. Forest entomology in Hawaii. Bernice P. Bishop Museum Special Publ. 44:266 pp.